Coordination Through Institutional Roles in Robot Collectives (Extended Abstract)

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Abstract

In this paper, we demonstrate the benefit of role allocation in a collective of autonomous robots performing a simple transport task. We demonstrate that, under certain conditions, the performance of the collective can be improved when a subset of the robots assume institutional roles as traffic regulators. The concept of institutional roles is part of a high-level approach to the control of multi-robot collectives called Institutional Robotics. We compare the institutional robotics approach to a swarm robotics approach. Based on results of experiments in simulation, we conclude that the coordination provided by the traffic regulating robots improves performance for large collectives, but for small collectives the performance is higher when all robots are directly involved in carrying out the task.

1 Introduction

Existing approaches to the organization and control of multirobot systems ranges from central coordination and tight collaboration between the constituent robots to self-organization exclusively through local interactions. In the past, we have suggested a novel high-level approach to the design and control of multirobot collectives, namely *institutional robotics* (IR) [2, 3], which takes institutions as the main tool of social life of robots. One particular form institutions can take is *institutional role*. In this paper, we demonstrate a concrete example of how the concept of institutional roles can improve the task-execution performance of a robot collective. Our experiments were designed to be conducted on the *e-puck* robots [1], with local communication capabilities. We report the results of experiments performed in a realistic simulator (Webots).

2 Task Description and Setup

In this study, robots must transport a virtual payload in an arena containing two rooms and a corridor. The robots pick up the virtual payload in the left room. They must then navigate through the corridor and deploy the payload in the right room. The corridor connecting the rooms is too narrow for two robots moving in opposite directions to pass one another. Thus, the robots must traverse the corridor in one direction at a time. Robots need to cooperate to avoid collisions and deadlocks in the corridor. In order to facilitate coordination, we let a subset

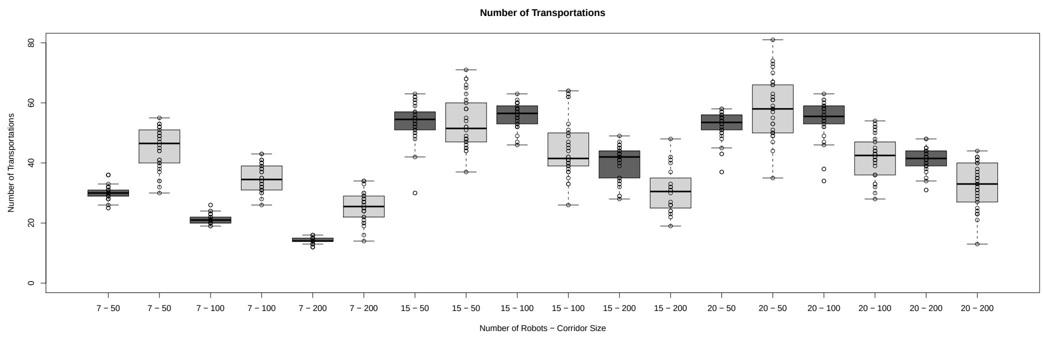

Figure 1: Distribution of number of transportations for different sizes of collective (IR in dark grey, SR in light grey).

of the robots adopt the institutional role of "traffic regulators" to control the circulation of the remaining robots in the collective.

If the need of traffic regulating robots arises due to a conflict between robots in the corridor, two robots assume the role as traffic regulators. The two traffic regulators place themselves at the opposite ends of the corridor so that each regulator can control the flow of transporting robots entering the corridor from one of the rooms. The goal of the regulators is to ensure that robots only move through the corridor in one direction at a time. The regulating robots are synchronized so that only one of them will let transporting robots enter the corridor from their respective rooms at any one time.

A traffic regulator periodically emits messages when it has to prevent transporting robots from entering the corridor from the room in which it is placed. If a transporting robot receives a message to stop, it will stop and begin to relay the stop message to other transporting robots behind it. As a result, the transporting robots will form a queue. When the first robot in the queue receives a message to proceed, it forwards the message to any robots that may be behind it, and the queued up robots will start to move.

We implemented a different solution to our task which does not use institutional roles to regulate traffic. This solution is based on the principles of swarm robotics and the robots rely exclusively on self-organization to solve the task. Conflicts between robots moving in opposite directions in the corridor are solved in the following way: whenever a robot moving in one direction encounters a robot moving in the opposite direction in the corridor, it waits for a period of time proportional to the time that it has been in the corridor. If this period of time expires, the waiting robot turns around and heads back to the side of the arena from where it came. Otherwise, if a waiting robot detects that the other robot gives up, it continues to traverse the corridor. We refer to this solution as the swarm robotics (SR) approach.

We prepared different setups in order to evaluate how parameters such as the size of the robotic collective and the length of corridor affect the performance. Three different corridor lengths (50 cm, 100 cm and 200 cm) were considered. For each corridor length, we ran experiments with different numbers of robots (7, 15 and 20 robots). For each of the nine resulting setups, we repeated the experiment 30 times for both the proposed IR approach and for the SR inspired approach. Each run had a duration of 15 minutes.

3 Results and Discussion

In order to compare our two approaches, several performance measures can be used. As the goal of the task is for the robots to transport a virtual payload, it is intuitive that the most important measure is the number of successful transportations (a pick up in the left room followed by deployment in the right room) by the collective.

In Fig. 1, we have plotted the distributions of the number of transportations for all nine experimental setups. The first 6 boxes from the left report on results for collectives of 7 robots, the middle 6 boxes on results for 15 robots, and the right 6 boxes on results for 20 robots. The results for the IR approach are presented in dark grey while values for the SR approach are presented in light grey. The number of transportations decreases as the length of the corridor increases. This is naturally explained by the fact that the robots spend more time traversing the longer corridors.

Collectives of 7 robots following the SR approach manage to perform more transportations than the robots following the IR approach. While in SR approach, all the robots are devoted to transporting virtual payload, in the IR approach two of the robots instead assume the roles as traffic regulators. This means that some of the collective's resources are spent on coordination. As the size of the collective increases, an inversely proportional share of robots are devoted to coordination (28.5% for 7 robots, 13.3% for 15 and 10% for 20). This is reflected in the larger number of transportations achieved by the larger collectives following the IR approach.

4 Conclusions and Future Work

In this study, we have shown that coordination devices set up as institutional roles can effectively help a robotic collective organize and improve performance in a given task. We have also demonstrated how concepts from institutional robotics can be applied in a real scenario, focusing on one specific form of institution, namely the institutional role. Our goal for the near future is to explore more concepts from institutional robotics, for instance, material artifacts and cooperative decision-making.

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